THE WEATHER AND CIRCULATION OF SEPTEMBER 1965

Prolonged Cooling in the West Related to Retrogression

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1. MONTHLY MEAN CIRCULATION

NORTH AMERICA AND NEARBY OCEAN AREAS

Retrogression of long waves was the dominant characteristic of the circulation over much of the western portion of the Northern Hemisphere the last few months. This retrogression is shown in figure 1, the paths of height anomaly centers, June through September 1965. Ordinarily there is a seasonal migration of some mean features as the continent becomes a heat source and the maritime areas become relatively cool. Normal charts [1] show this quite well as the trough off the Atlantic coast moves into eastern North America during the warm months. Similarly the ridge over the Southeast in June reappears over the Plains by midsummer. However, the retrogression as it continued into September 1965 (figs. 1, 2) exceeded the normal seasonal shift of troughs and ridges. The greatest density of ridge lines in or near North America in the last 15 years [2] was around 120° W., but the ridge in September 1965 was near 130°–140° W.

The tracks of height anomaly centers indicate reasonably regular westward motions in the various latitudes. These motions should not be assumed as continuous as may be suggested by the diagram. For example, during August [3] there was a trough along the west coast, out of phase with a ridge to the north. Associated with the trough was a negative 700-mb. height anomaly that moved eastward to the Rocky Mountains during the first half of September. Meanwhile the ridge formerly in the eastern Pacific came into phase with the ridge that was over northwestern Canada. Amalgamation with the high-latitude ridge ensued and instead of a blocking regime with split planetary wave paths, a large-amplitude wave pattern was formed with little broadscale confluence and with a coherent wave train.

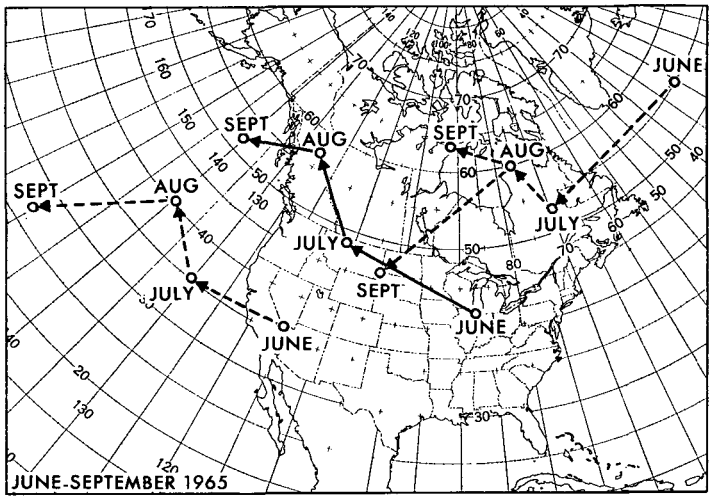

FIGURE 1.—Positions of selected monthly mean 700-mb. height anomaly centers, June to September 1965. Solid lines connect positive anomaly centers and dashed lines connect the negatives. Successive positions farther west show the long-period retrogression of planetary waves.

The extent of this ridging can be seen in figure 3, the monthly mean 700-mb. height departure from normal, and in the magnitude of the anomalous height change from August, shown in figure 4. Height increases of 550 ft. in the Gulf of Alaska in September replaced the negative anomaly of August to produce this large ridge whose maximum height was 480 ft. above normal. This was a record height anomaly for September, regardless of sign, for North America and adjacent ocean areas (monthly mean charts available from 1933).

Upper-level flow in the Gulf of Alaska and the eastern Pacific frequently determines the upper flow and the weather over the United States. September 1965 was an outstanding example.

In response to the full-latitude ridge over the eastern Pacific was the full-latitude trough over North America (fig. 2). This deep trough extended from eastern Canada through the Northern Plains and Rocky Mountains to southern California with a negative height anomaly of 200 ft. over northern Hudson Bay. In the Northern Plains, 700-mb. contour curvature was cyclonic where it is usually anticyclonic in September, and heights were 180 ft. below normal. Although negative height anomalies were relatively small they affected the western two-thirds of the Nation. Height increases in eastern North America (fig. 4) reflect some ridging, but in eastern Canada the rises resulted mostly from the retreat of the upper-level cyclone formerly near Baffin Island where it was much deeper.

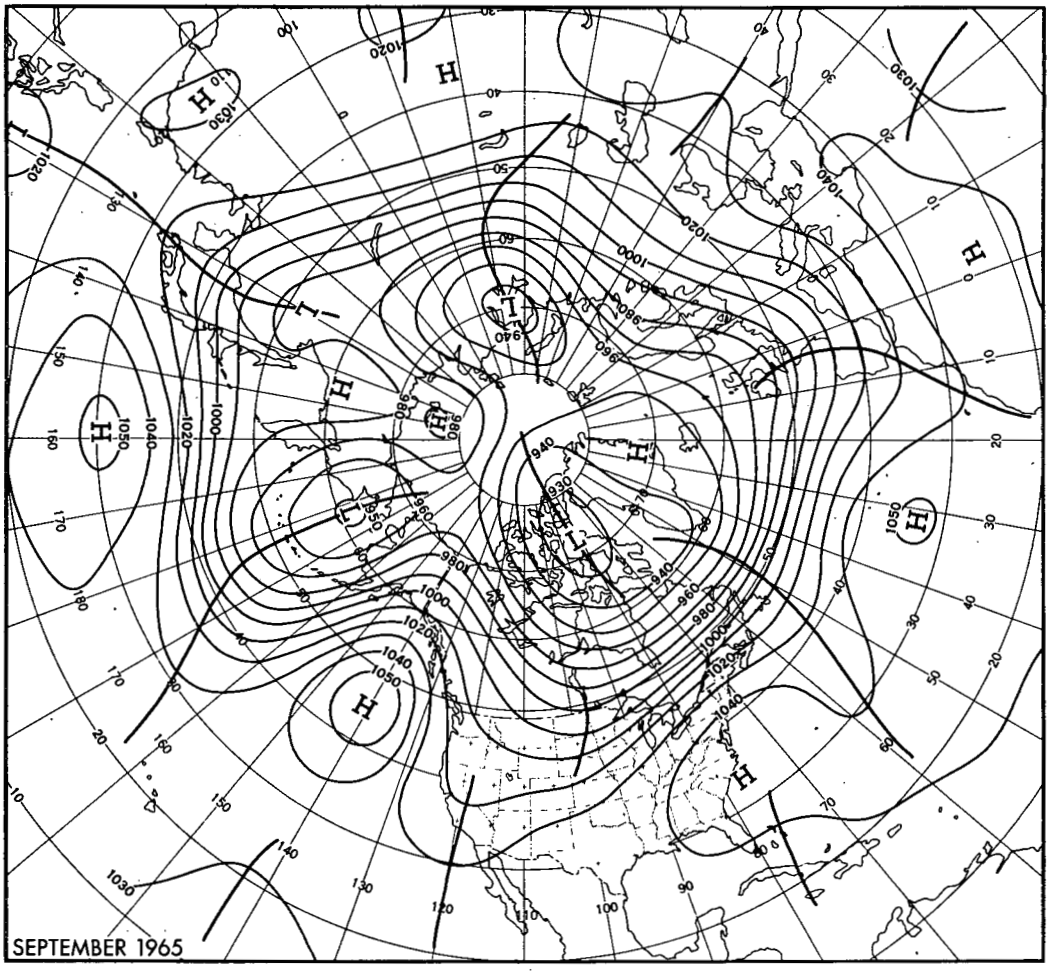

FIGURE 2.—Mean 700-mb. contours (tens of feet) for September 1965. Cyclonic flow in the Northern Plains, where contours are normally anticyclonic [1], was a response to the strong ridge in the Gulf of Alaska.

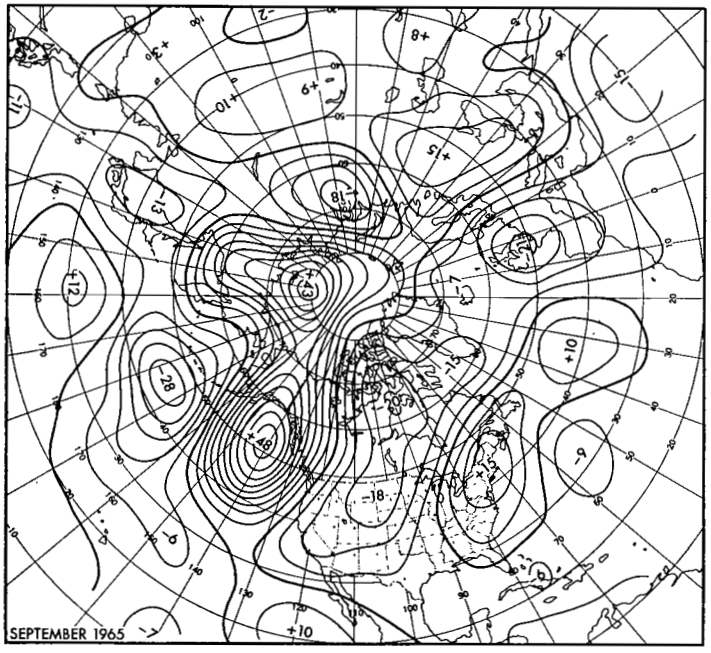

FIGURE 3.—Departure of mean 700-mb. heights from normal (tens of feet) for September 1965. Strong meridional flow over the United States was associated with the record height anomaly in the Gulf of Alaska.

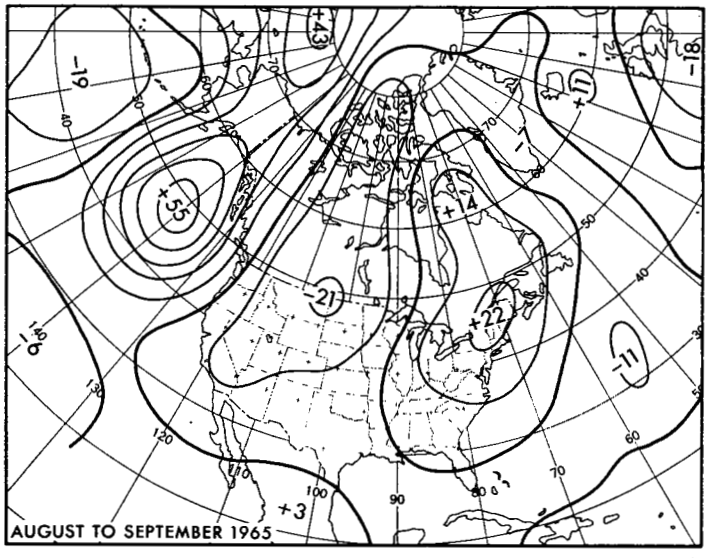

FIGURE 4.—Mean 700-mb. height anomaly change (tens of feet) from August to September 1965. These changes were reflected in the change in zonal westerly index (35°–55° N., from 5° W. to 175° E.) from 2 m.p.s. above normal in August to 4 m.p.s. lower than normal in September.

From the Great Lakes to the central Atlantic further amplification was inhibited, principally as a result of the influence of the large polar cyclone. Zonal flow in the westerlies from 45° to 55° N. developed here and average wind speeds were 10–15 m.p.s. Heights were above normal in middle latitudes and, with the axis of the Atlantic ridge north of it usual position, heights in lower latitudes were somewhat less than normal. This pattern of height anomaly is frequently conducive to tropical activity in the western Atlantic and the Gulf of Mexico.

CIRCULATION ELSEWHERE

Strong meridional flow prevailed over Europe and most of Russia (figs. 2, 3). An extensive trough was located from the United Kingdom to the coast of North Africa and averaged more than 200 ft. lower than normal. Troughs have been common the last 15 years in September from the Bay of Biscay southwestward along the African coast [2]. In the United Kingdom, however, monthly mean troughs have seldom been observed in September. At this latitude troughs in September have been found most frequently between 20° and 30° W. However, the strong westerlies in mid-Atlantic may have accounted in part for the unusual location and depth of the trough this September.

Over Asia the deep Low near 70° N. and the trough associated with it and the ridge to the east were not displaced appreciably from long-term average positions. The flow was not notably strong but the axis of maximum 700-mb. wind was south of normal from Scandinavia to western Siberia, and heights were slightly above normal, suggesting weak blocking over this area.

Eastern Asia was dominated by strong, high-latitude blocking and heights were 700 ft. above normal. Interrelated with this blocking were the trough along 130° E., the strong westerlies near 40° N. to the east of Japan, and the very deep trough in the central Pacific.

2. WEATHER IN THE UNITED STATES

TEMPERATURE

Several times this month very cold air masses that originated in western Canada had a trajectory generally into the Northern Plains States then across the Great Lakes (Chart VIII of [4]). On two occasions very cold Highs plunged to the Southern Plains States before moving eastward. Since the 700-mb. flow (fig. 2) was northwesterly from the Beaufort Sea to the Northern Plains States, there was little moderation of temperature that could be attributed to the passage of maritime systems. In fact it was only during the last three days of September that the eastern Pacific ridge finally gave way and permitted milder Pacific flow into western North America.

Sustained flow from a cold source region with below normal 1000–700-mb. thickness (fig. 5) thus resulted in unseasonably cold average conditions in the Northern

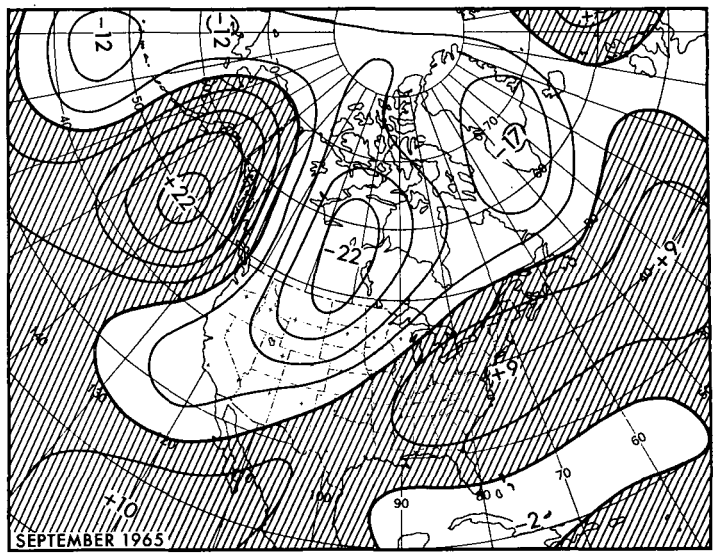

FIGURE 5.—Departure of average 1000–700-mb. thickness from normal (tens of feet) for September 1965. Lower than normal thickness was widespread over North America with above normal thickness over Alaska and the eastern third of the Nation where surface temperatures were a few degrees higher than normal.

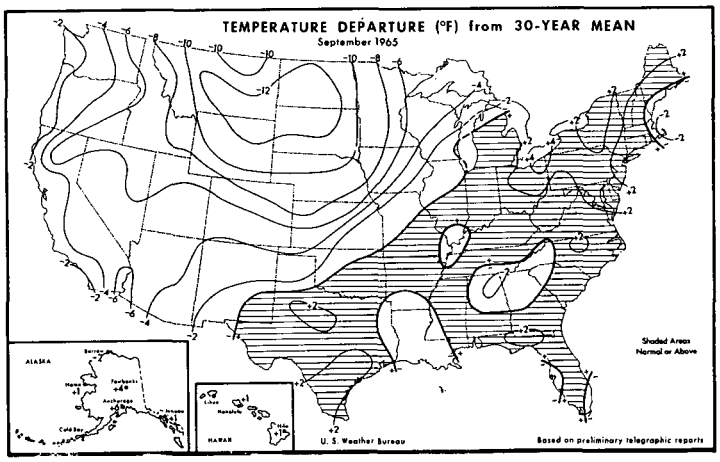

FIGURE 6.—Surface temperature departure from normal (°F.) for September 1965 (from [5]). Repeated outbreaks of Polar air with little intermediate moderation created many new temperature records.

Plains where temperatures for September (fig. 6) were 8°–14° F. lower than normal and 4°–8° F. below normal elsewhere in the area from Washington to Wisconsin to Arizona. Cold weather prevailed here throughout the month and resulted in the coldest September of record at all first-order stations in Montana. Record low September mean temperatures were also observed in Minnesota, North and South Dakota, Iowa, Nebraska, Colorado, Utah, Idaho, and California.

Record-breaking low temperatures for so early in the fall were also observed during the third week (fig. 7). Some representative minima were Lander, Wyo. (10° F.),

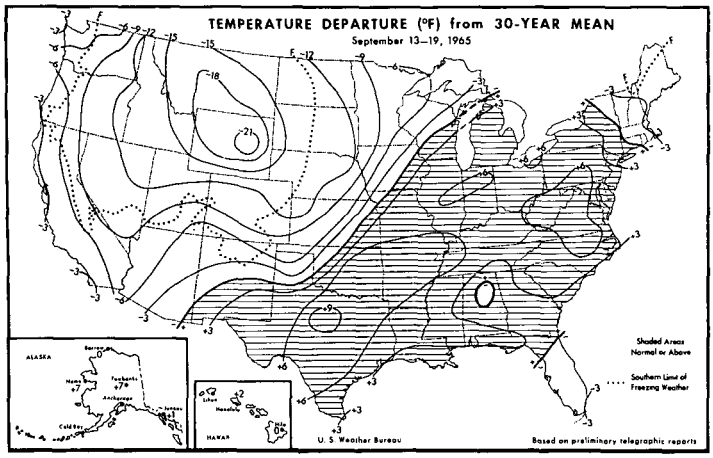

FIGURE 7.—Surface temperature departure from normal (°F.) for September 13–19, 1965 (*from* [5]). *Record cold in the West and a heat wave in parts of the South and East accompanied the very strong circulation pattern this week.*

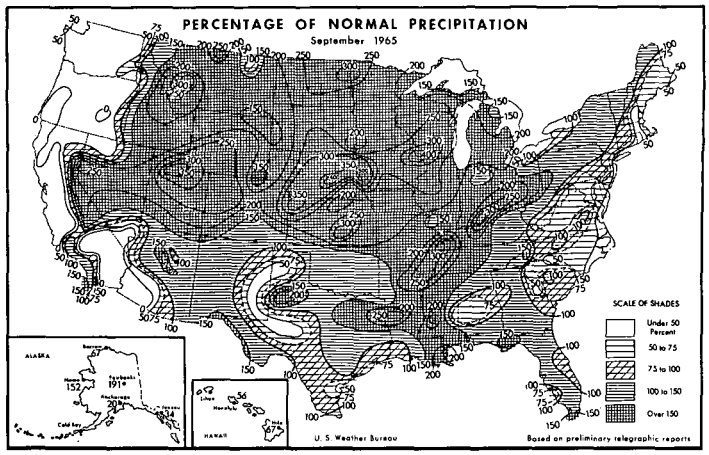

FIGURE 8.—Percentage of normal precipitation (in.) for September 1965 (*from* [5]). *Record rains in the Plains and record snowfall in the Rockies were associated with the active mean trough. More than twice normal rain in the Ohio and lower Mississippi Valleys occurred mostly in the 2d week with the passage of hurricane Betsy.*

St. Cloud, Minn. (22°), Ely, Nev. (16°), Sheridan, Wyo. (15°), and Yakima, Wash. (30°). Freezing temperatures or lower extended from the Northern Plains to the inland mountains of the West Coast States and as far south as northern New Mexico and Arizona. As noted earlier there was some moderation in the fourth week of September as normal temperatures returned to the Northwest. However, temperatures were still 12°–15° F. lower than normal from the Dakotas to the Texas Panhandle.

Temperatures were normal to a few degrees above from Texas to New England this month. This area was generally subject to southerly flow (fig. 2), above normal 700-mb. heights (fig. 3), and above normal 1000–700-mb. thickness (fig. 5). A heat wave spread over much of the South and East the third week (fig. 7) during the period when it was coldest in the West. Temperatures were 6°–9° F. above normal over portions of Texas, the lower Mississippi Valley, and the Middle Atlantic States. Maximum temperatures in the 90's were common and some were above 100° F. in northern Texas and Oklahoma. At this time temperatures in the northern Rockies were near zero. Subsequently the cold air pushed eastward the last few days of the month

Temperatures of note in Hawaii and Alaska include 93° F. at Honolulu, a record maximum for September; at Nome 63° F. was the highest temperature ever recorded for so late in the year.

PRECIPITATION

Heaviest precipitation relative to normal this month fell in the Rocky Mountain and Central Plains States and in the Ohio and Lower Mississippi Valleys (fig. 7). Normal or less precipitation fell in the West Coast States, portions of the Southwest, and along much of the Atlantic seaboard.

In the Midwest large amounts were related primarily to the position of the mean trough (figs. 2, 3). Strong southwesterly anomalous flow implies an actual flow with frequent strong southerly components for much of the month. This was a means of transporting moisture from the Gulf of Mexico to higher latitudes. With a high frequency of fronts in the Midwest there were frequent and heavy instability showers that helped produce two to three times normal precipitation. Monthly precipitation records established in September are shown in table 1.

Snowfall came to the Rockies and to portions of the Great Plains over a 3-day period associated with the strong cold outbreak of the 3d week. This was described as the most severe storm for so early in the season over the last several decades. Snowfall records were broken in many States as accumulations were noted as far south as northern Arizona. Several cities received record snowfall for September, the most for so early in the season, and the greatest 24-hour amounts in September. Salt Lake City, Utah, with more than 2 in. on the 17th, had its first measurable September snowfall.

TABLE 1.—*Record precipitation for September established in 1965.*

City	Rainfall (in.)	Departure from normal (in.)
Dubuque, Iowa	15.46	+11.72
Omaha, Nebr	13.75	+11.12
Sioux City, Iowa	9.69	+6.95
Grand Island, Nebr	9.00	+6.85
Cold Bay, Alaska	9.79	+5.47
Columbus, Ohio	7.28	+4.96
Green Bay, Wis	7.80	+4.88
Cincinnati, Ohio	7.48	+4.77
Helena, Mont	3.37	+2.42
Juneau, Alaska	2.34	−4.33
Annette, Alaska	2.52	−7.36

Most of the heavy rain in the Gulf Coast States was associated with tropical activity. With the passage of hurricane Betsy, 2–4 in. fell in southern Florida and 4–6 in. fell when this storm entered Louisiana and moved up the Ohio Valley. Another storm that originated in the Tropics produced several inches of rainfall on September 29 and 30 as it moved across northwestern Florida and spread rains across several States. On the dates above, the Mobile, Ala., city office reported a 24-hour record fall of 16.85 in., accompanied by heavy flooding.

REFERENCES

1. U.S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper* No. 21, Oct. 1952, 74 pp.
2. L. P. Stark, "Positions of Monthly Mean Troughs and Ridges in the Northern Hemisphere, 1949–1963," *Monthly Weather Review*, vol. 93, No. 11, Nov. 1965, pp. 705–720
3. R. A. Green, "The Weather and Circulation of August 1965—A Cool Month," *Monthly Weather Review*, vol. 93, No. 11, Nov. 1965, pp. 721–726.
4. U.S. Weather Bureau, *Climatological Data, National Summary*, vol. 16, No. 11, Nov. 1965, Chart VIII.
5. U.S. Weather Bureau, *Weekly Weather and Crop Bulletin, National Summary*, vol. 52, Nos. 38, 40, 41, Sept. 20, Oct. 4, Oct. 11, 1965.

New Weather Bureau Publications

Technical Paper No. 55, "Tropical Cyclones of the North Atlantic Ocean," George W. Cry, 1965, 148 pp. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price 70 cents.

Charts showing tracks of North Atlantic tropical cyclones by years, 1871–1963 and broken down into monthly or other calendar periods are preceded by descriptive text on features of formation, intensity, and paths. A short discussion of possible trends in tropical cyclone frequency is also included. This work amplifies but does not supersede *Technical Paper* No. 36, 1959.

Research Paper No. 46, "Application of Synoptic Climatology and Short-Range Numerical Prediction to Five-Day Forecasting," William H. Klein, 1965, 109 pp. For sale by Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Price 60 cents.

Multiple regression equations are derived for specifying and predicting 5-day precipitation amounts, surface temperature anomalies, mean 700–1000-mb. thickness, and mean and daily sea level pressure from concurrent and prior anomalies of the 700-mb. height field. The regression equations are applied under operating conditions to prognostic 700-mb. heights produced by baroclinic and barotropic numerical prediction models for periods from 24 to 96 hr. in advance. The verified forecasts are found to compare favorably with predictions produced by several controls and by other forecast methods.